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GENETICS IN THE U.S.S.R.*

For more than ten years, biologists have been puzzled by reports from the U.S.S.R. about the 'new genetics' of Lysenko and his school. According to these reports, Lysenko had repudiated Mendelism, and in its place he had established a new genetics, founded on the authority of Darwin and Michurin, and elaborated from his own experiments. The new genetics took no account of segregation. It did not admit phenotype or genotype. It denied that chromosomes played any special part in heredity. It claimed that inherited characters were transmitted through the sap from stock to scion in grafts. It demonstrated that in open pollination, picturesquely called 'love marriage', the ovum selects the gamete it desires. It contrasted the outward appearance of a plant, called its 'shirt', with its physiological character, called its 'soul'. It condemned the work of Mendel, Bateson and Morgan as clerical, bourgeois-capitalistic and fascist. It disdained the use of statistics, controls and such-like experimental techniques. It fought its way to recognition with the weapons of the medieval schoolmen: appeal to authority; *a priori* assumptions based on dialectical materialism; and the compelling pragmatic test that, by the new genetics, nurture henceforth takes charge over nature.

The intellectual eruption, needless to say, severely shook Soviet biology. There was a period during 1932-40 of bitter controversy. Vavilov and Karpechenko vanished during the fight. Serebrovsky and Dubinin retired disillusioned to their institutes. But Lysenko received the applause of the Soviet press and was awarded various public honours. It seemed to biologists outside the U.S.S.R., who were unable to weigh the issues for themselves, that the new genetics had ousted the old.

Lysenko writes in such an obscure style that a knowledge of Russian alone is quite inadequate equipment for a study of his views; one needs to know also something about the Russian character, and something about the appreciation of dialectical materialism to science. Dr. Hudson and Mr. Richens have all these qualifications, and they have written an important essay†, in which they summarize in a masterly way the philosophical and psychological origins of Lysenko's views, the experimental evidence, and the logic (or lack of it) used to interpret this evidence.

* A Review (abridged) by E. Ashby reproduced from *Nature*, 158, 285, 1946.

† The New Genetics in the Soviet Union.
P. S. Hudson and R. H. Richens. p.p. 88 (Cambridge: Imperial Bureau of Plant Breeding and Genetics, 1946.) 6s. net.

Fantastic as Lysenko's claims may appear to British biologists, they nevertheless deserve careful examination—we did, after all, overlook Mendel for thirty-six years. Hudson and Richens have disengaged the problem from all the violent prejudices which surrounded it. They have approached it in the best traditions of scholarship; important quotations are even reproduced in the original Russian in footnotes, and there is a summary in five languages. They are most sympathetic to Lysenko. They are so anxious to do him justice that they excuse his naive terminology and his ignorance of contemporary genetics; and they are almost orientally apologetic every time they bring a verdict against him. Thus on the question as to whether Lysenko's evidence for 'love marriages' among mass pollinated plants is convincing, they conclude: 'It is difficult to come to any answer other than a decided negative'. The whole essay is a virtuoso piece of literary meiosis. Lysenko could not have had his case put more fairly: indeed, he could not have put it nearly so fairly himself.

And what is the case? Hudson and Richens show how the new genetics has its source in Darwin, often for some tentative suggestion Darwin made; so that Darwinism in Russia means something quite different from Darwinism in England. They show how Darwin's views have been clothed in the language of dialectical materialism. They record how, in 1932, a resolution was passed in Leningrad that genetics and plant breeding were to conform with dialectical materialism, so that Lysenko enlisted the State on his side. They give the most objective account ever written in English of the controversy during 1932-40. They examine the argument by authority and the denunciation of the seven heresies of genetics. They describe Lysenko's use of the 'elastic hypothesis' which contains all the facts you like and explains none of them. They review the experimental evidence for the control of heredity by environment, and they reluctantly decide it is 'not compelling'. They discuss Lysenko's interpretation of this evidence, and they register gentle but firm disapproval. They give a resume of Lysenko's destructive attack on Mendelism.

In spite of the author's urbanity, the new genetics emerges from this essay in a pretty bad state. Lysenko claims to have changed heredity by manipulating the environment and to have rejuvenated pure lines by intravarietal crossing: the authors show that his experiments are capable of their interpretations quite consistent with the old genetics. Lysenko claims to have influenced the heredity of plants through grafting: the authors show that his data are incapable of any interpretation, and that one of his tables is even inconsistent within itself. Lysenko claims to have demolished the old genetics: the authors show that his criticisms are applicable only on the genetics of thirty years ago. Lysenko's attitude to modern genetics outside his own school is one of militant obscurantism. Hudson and Richens, by contrast, have analysed the most improbable claims of the new genetics with quiet care; and they even support Lysenko's just complaint that other geneticists have not taken the trouble to repeat his experiments.

The authors point out that they cannot offer opinions on two matters of interest: the exact way in which Lysenko does his experiments, and the present state of the new genetics in the U.S.S.R. I can offer some comment on these two matters.

First, as to the experimental technique in the new genetics. The experiments are carried out on very small populations of plants. For example, an experiment on 'shattering' the heredity of winter wheat (to turn it into spring wheat) occupies a plot of ground about 7 ft. by 3 ft. An experiment on changing the nature of Wohltmann potatoes occupies two rows about 20 ft. long: one row, the control, is heavily infected with virus, though this was denied by Lysenko. An experiment on 'love marriage' in rye occupies about 7 ft. by 3 ft. of ground. Experiments on the transmission of heredity through grafts, using tomatoes, are done with about 20-30 plants, sometimes without controls. The technique of emasculation seemed unreliable to me; and I was told by Lysenko that it is only since 1940 that emasculated flowers have been bagged before polination; before that no precautions were taken to exclude stray pollen. Since Lysenko rejects the ideas of pure lines, no particular care is taken to use homozygous material for experiments; in fact, Lysenko seems to assume that any variety with a name to it is genetically homogeneous—an assumption which should not be made for Russian varieties. Some of the strains of tomatoes are markedly heterozygous, and some suffer from spotted wilt, which causes a mottling of the fruit which Lysenko attributes to a change in heredity. When experiments are carried into an F2 generation, not all the seed from a parent plant is sown, but only seed from 'selected' fruits or ears. Statistical treatment of the data is forbidden; it was a member of Lysenko's staff who said that Darwin's work is convincing without statistics; why should anyone require statistical evidence of Lysenko's work?

As to the present state of the new genetics in the Soviet Union, it is safe to assume that Lysenko's school is well past its zenith. It is true that he is still a great demagogue among the peasants and on the collective farms. It is true that, in the University of Leningrad, Turbin (who was the chair of genetics) and Prezent (who was the chair of Darwinism) maintain a school of the new genetics, and Sinnott and Dunn's text-book is passed in secret from student to student as though it were an inflammatory tract; and Lysenko has tried (see his Journal *Yarovizatsia*, 1939 and 1940) to suppress all teaching of Mendelism in Russia. But side by side with the new genetics there exists, in uneasy truce, a school of the old genetics which is setting the pace on world standards in such fields as population genetics and the use of colchicine-induced polyploids in plant breeding. The University of Moscow has flourishing genetics schools under Serebrovsky and under Schmalhausen, where Khvostova has recently repeated Lysenko's work on graft hybrids in tomato and shown that his results are due merely to heterozygosity. It is fairly safe to say that most biologists in the U.S.S.R., while ready to admit

Lysenko's skill as a practical agriculturist, are deeply embarrassed by the new genetics, and are gradually turning their backs on it.

Hudson and Richens have done a great service to international understanding in biology. They hope their work will remove prejudice on both sides. That is perhaps too much to hope; but if it exposes the new genetics as a throw-back to the days of Thomas Aquinas, it will undoubtedly be welcome, and not least in the U.S.S.R. itself.

RAT CONTROL IN HAWAII *

A very detailed account of the experiences obtained to date on the control of rats in sugar cane plantations in Hawaii has been published in the *Hawaiian Planters Record*†. There are four species concerned: the Polynesian rat, *Rattus hawaiiensis*, the smallest and most docile species, the Norway rat, *R. norvegicus*, the grey, brown or sewer rat and most pugnacious, the black rat *R. rattus rattus* and the Alexandrine rat, *R. rattus alexandrinus*.

The relative importance of these species varies according to the location of the cane fields in relation to the neighbouring natural growth. The Norway rat is the most abundant and formed 58 per cent. of the bag; the Polynesian rat was comparatively rare, but in certain localities has become abundant. The first two build and nest in burrows, the last two above ground with *Pandanus* (screw pine), a favourite resort. With sex maturity in three to four months, a gestation period of 21 days, and from four to eight young per litter, the potentialities of excessive multiplication are great. The only enemy of importance is the mongoose imported from India via the West Indies in 1883, and held to do more good than harm.

Rat population varies with the location, the most obvious influence being the natural cover. Where this is extensive, migration from this natural sanctuary into the cane fields is a major problem. It reaches a maximum between December and February and is probably due partly to the seasonal fluctuation in food supply and partly to increased population following the summer litters.

The best and most obvious method of control is the destruction of the natural cover. It is a remedy rather than a control; but, unfortunately, in terrain such as exists in Hawaii, a counsel of perfection. Tangible results, though slow ones, have resulted from planting up such trees as eucalyptus and ironwood (*Casuarina*) on wastes bordering the cane fields. Trapping has proved ineffective and gassing with calcium cyanide or chlorine has little practical usefulness in the field. Various virus preparations have been used without noticeable effect and reliance is now placed on poisoning.

Of all the poisons tried, thallium sulphate has proved the most effective until recently when, owing to the scarcity of this chemical, zinc phosphide was tried and found equally effective. It has the further advantage of eliminating secondary poisoning; i.e., the killing of animals eating the carcasses of poisoning rats. For bulk preparation of the former, 6 lb. 10 oz. sulphate and 53 lb. brown sugar dissolved in hot water (17.5 gallons) are sprayed into 1,260 lb. dry rolled oats in a closed mechanical mixer, the mixture being dried at 140°F. for seven hours. For the latter, one preparation is, 0.5 lb. phosphide and 0.25 lb. of mill lime stirred into 0.75 gallon corn oil and the suspension stirred into 100 lb. pre-dried rolled oats previously screened to remove the finer particles. Coconut cubes (0.5 in.) may also be shaken with a mixture of equal parts phosphide and lime.

Various trials have been made to make the baits more attractive in the case of torpedos for direct baiting, the primary object is to attract rather than supply an appetizer. Till recently, when it became difficult to procure, corn oil proved best; but white mineral oil (Standard Oil Co. No. 9) has proved at least as effective.

For direct baiting, the thallium bait is made up in twisted paper capsules (approx. 100 to 1 lb. bait). These are scattered widely in the cane fields, some 200 per acre, or surrounding wastes. Owing to their reaction to moisture, zinc phosphide baits are unsuited for this purpose. For pre-baiting, the bait is put dry into galvanized trays covered by half-cylinder covers. Pre-baiting has been developed to a high art. If carried out thoroughly in young cane it can later be limited to borders. The stations vary from 75-100 ft. apart along road and trails, but along wasteland borders a closer spacing of 45-50 ft. apart is desirable. The principles of pre-baiting is the exposure of unpoisoned bait for a period until rats have learned to recognize the stations, and then the substitution of poisoned bait. The first pre-baiting period lasts some ten days with visits after four and seven days to replenish the bait. Poisoned bait is then substituted and left for three days. The amount of poisoned bait consumed is approximately one-third of the unpoisoned previously eaten. The amount of unpoisoned eaten, and therefrom the amount of poisoned bait required at each station, is roughly indicated by an arrow on the cover set to point to 3, 6, 9 or 12 (clock face) according to the number of cups or measures of unimposed bait supplied during the pre-baiting period.

The interval between baiting periods depends on extent of rat migration. Inspection at frequent intervals is, therefore, necessary. Normally treatment at four month intervals is adequate but, with adjacent cover and at the peak of the migratory season, the frequency may be carried to every four or six weeks.

* Reproduced from *Int. Sug. Jr.* 68, 39.

† R. E. Doty, Rat Control on Hawaiian Sugar Cane Plantations, *Hawaii, Plant. Rec.*: 49, 71-139.

THE SIGNIFICANCE OF CARBON-NITROGEN RATIO IN SOILS GROWING COTTON

(II) The Soils and Climates of the Britsh West Indies Cotton-Growing Islands

BY

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(I) Introduction

IN Part I of this article*, certain striking carbon-nitrogen relationships obtaining in the cotton soils of Queensland, Australia, were considered. There it has been demonstrated that characteristic differences in the growth phenomena and yields are manifest in cotton crops grown on lands newly brought in from forest or from grass as contrasted with lands which have been producing cotton for a number of years. Whereas normal growth and high yields are usually associated with new lands, the crops planted on old lands tend to "bolt", that is, to develop prolific dark-green sappy growths which produce only few bolls and are very susceptible to insect attack. This old land effect has been traced to over-production of nitrate† in the soil favoured by a narrowing carbon-nitrogen ratio accompanying the gradual wastage of soil organic matter. Other results of this change are attributable to deterioration in physical structure which profoundly alters the water relations of the soil and the plant. As would be expected, these effects are shown in greater degree and in shorter time by some soil-types than by others, the more stable and resistant soils generally being those having high calcium status.

The climate of the cotton-growing region of Queensland is relatively dry (rainfall less than 30 inches a year) and the rainfall is sporadic and most irregular. The future of the crop in any one year is largely decided by the amount of available moisture in the soil at the time of planting (late winter) and by the quantity and regularity of the spring and early summer rains. Particularly with soils having low carbon-nitrogen ratio, moist conditions favour bolting and insect damage, resulting in low cotton yields. On the other hand, with soils having high carbon-nitrogen ratio, moist conditions produce normal growth and adequate fruit setting and good crops are obtained. In either case conditions that are unusually dry inhibit plant growth and the crops may fail. The ideal weather for rain-grown cotton in Queensland is regular rainfall to maintain a steady water-supply in the soil during the vegetative phase and open sunny weather during the reproductive phase with sufficient rainfall to prevent wilting.

*The significance of carbon-nitrogen ratio in soils growing cotton: (I) The cotton soils of Queensland, Australia: By F. Hardy, *Tropical Agriculture*, XXII, 1945; pp. 119-127.

†For example, new land usually shows no soil nitrate on chemical analysis, whereas land after one year in cotton shows about 14 p.p.m. of soil nitrate and old cultivations show 30 to 50 p.p.m.

(II) West Indian Cotton Soils

With the object of applying the general principles revealed by the Queensland investigations to cotton-growing in the British West Indies, the results of soil analyses performed at the Imperial College of Tropical Agriculture during the past ten years on a large number of representative soil samples collected in the different islands have been tabulated and classified under their provisional soil-types.

The insular cotton-growing areas for which adequate comparable laboratory data are now available are St. Vincent, Montserrat, Nevis and St. Kitts; these comprise the main islands where cotton is grown in the British West Indies though the crop is also grown on a small scale in Barbados, Carriacou, Union and Antigua.

(1) CHIEF SOIL-TYPES: The four main islands resemble each other geologically in that they are built up of fragmental volcanic rocks with only minor quantities of lava. The fundamental petrological rock-type is andesite. In St. Vincent, the chief rocks are hypersthene-andesite with some basalt; in Montserrat and Nevis, quartz-andesite; in St. Kitts, both sorts occur in about equal amount. The physical rock-types range from fine dust through sand, "ash", cinders and stones to large boulders. These form stratified deposits laid down in water (aqueous tuffs) or spread out over the slopes of volcanic cones ("black cloud" deposits and ash showers), or tumultuous heaps showing no regular arrangement. The finer kinds of ejecta comprise most of St. Vincent where large stones and boulders are scarce, whereas the coarser kinds predominate in the three other islands, particularly Nevis.

The degree of decomposition of the volcanic rocks varies greatly depending on rainfall and length of time of exposure both of which range between wide limits, so that the weathered material from which the soils are formed differs markedly in chemical and physical features, and has given rise to several distinctive soil-types the chief of which are briefly described below.

(i) *Alluvial-Colluvial Soils:* These are developed over recent aqueous deposits occurring along the coasts, within deltas, along river banks or over débris occurring at the bases of hills. They show no marked profile; their mechanical texture varies from fine sand to large boulders.

Coastal and deltaic alluvial soils occur to small extent in St. Vincent and Montserrat, but river alluvial soils are nowhere abundant in any of the Islands. Colluvial soils occur sporadically in all four Islands.

(ii) *Lithosol :* This type is derived from geologically-recent fragmental volcanic rocks of various size grades only slightly decomposed. It shows no marked profile and resembles a heap of loose sand, stones or cinders with a thin humic layer on top. In many cases old buried humic layers occur at different depths marking successive eruptions.

Lithosol covers the northernmost third of St. Vincent, including the slopes of Soufriere, a recently-active volcano. In Montserrat it occupies the lower grounds around the southern half of the coastline. It also covers the summit of Nevis Peak and forms a belt over its leeward slope down to the coast. In St. Kitts, it covers most of the northern half of the Island.

(iii) *Yellow Earth :* This is developed over the products of hydrolytic weathering of volcanic sand or ash. The parent material consists of discrete mineral grains variably decomposed ; the felspar crystals have been mostly converted into kaolinic pseudomorphs, stained yellow by limonitic iron oxide derived from the ferromagnesian minerals, but magnetite has scarcely been affected, so that the material has a pepper-and-salt appearance. It is very porous, loose and permeable. Calcium carbonate is prevalent among the products of decomposition ; Yellow Earth profiles are thus usually alkaline in reaction and show many of the calcimorphic features of Rendzina, for example, a thick sepia-black friable humic layer on top having a marked granular structure, and a concretionary calcium carbonate layer below at variable depth.

Yellow Earth is most typically developed in St. Vincent where it occupies the southern two-thirds of the Island. It also occurs in Montserrat in the St. George's Hill District and as a concentric strip bordering the Lithosol. In St. Kitts, it forms most of the low ground around the southern hill masses. It appears to be absent from Nevis.

(iv) *Brown Earth :* This resembles the last except that it is derived from coarse fragmental rocks (agglomerates) rather than fine-grained ejecta, and its iron oxide products of decomposition are redder in colour. The component boulders and stones are usually deeply weathered and softened, the cracks being lined with blue-black manganese oxide. Brown Earth shows calcimorphic features, being generally neutral to slightly acid in reaction, though typically devoid of calcareous accumulations within the six-foot profile. It is developed under a wetter climate than Yellow Earth and is a more mature type.

Brown Earth occurs only in Montserrat among the four Islands ; here it occupies the higher ground above the 600-800 foot contour surrounding Soufriere Hills and South Soufriere Hill comprising the southern half of the Island.

(iva) *Rendzina :* This soil-type is usually developed over marls and highly calcareous clays. It is characterised by a thick intensely black humic layer having a marked crumb structure and a neutral to slightly acid reaction. The parent clay is golden-yellow to grey, and concretionary calcium carbonate may occur in it at variable depth, or within the marl itself.

Rendzina occurs only in the Bransby Ridge District of Montserrat where it occupies a few fields of small area. Here a deposit of white solfataric or tuffaceous calcium carbonate encrusts the component boulders of an otherwise normal agglomerate.

Rendzina comprises the black soils of Barbados, Antigua and Carriacou, being there developed over soft limestones and marls.

(v) *Terras :* This merges with Yellow Earth and is differentiated therefrom mainly by the occurrence of a clay-pan generally starting at about 12 inches depth and having variable thickness up to several feet. The clay-pan probably originates in the downward leaching of siliceous material and develops through the formation of beidellite clay mineral. It causes drainage impedence. Terras Soil is more clayey than the other types so far considered ; it is also more acid in reaction and shows a lower calcium status, otherwise it somewhat resembles Yellow Earth and often exhibits a pepper-and-salt appearance.

Terras Soil occurs sporadically in the western, southern and eastern parts of the coastal belt of St. Vincent. It is typically represented in western Montserrat in the Elberton District, but its occurrence in Nevis and St. Kitts is doubtful.

(vi) *Shoal :* This may be developed either over cemented agglomerate that forms the old basement of the volcanic islands ("geological shoal") or over fragmental materials in which clay-pan formation has completely sealed up the subsoil ("pedological shoal"). Drainage impedence is extreme in this soil-type. The soil is a gritty or sandy clay, slippery when wet ; hard, horny and deeply cracked when dry. Its colour is pale chocolate-brown to khaki. Its reaction is somewhat acid and its calcium status relatively low. Sometimes a mottled "gley" layer occurs above or within the clay-pan.

"Geological" Shoal occurs typically in the Silver Hill District of Montserrat, as well as over most of the lower grounds of Nevis and in the southern peninsula of St. Kitts. "Pedological" Shoal occurs along with Terras in the southern coastal area of St. Vincent and over the lower slopes of Centre Hills in Montserrat (*e.g.*, Olveston District), and also in parts of Nevis.

(2) Soil Classification: It is evident from these descriptions that the main soil-types differ in drainage features, the first four being more-or-less freely drained whereas the last two show increasing drainage impedence coincident with their greater degree of maturity. According to pedological principles, the six soil-types would be classified thus*:—

(I) *Azonal Soils*
(Free-draining)
(1) Alluvial-Colluvial Soils
(2) Lithosol

*See "Soils and Men" ; U.S.D.A. Year Book, 1938 ; pp. 979-1001. The writer prefers the term "calcimorphic" to "calomorphic" as applied to types dominated by calcium-ion.

(II) *Intrazonal Soils*
(A) *Calcimorphic*
(Free-draining ; calcium dominant)
(3) Yellow Earth Soil
(4) Brown Earth Soil
(4A) Rendzina
(B) *Hydromorphic*
(Impeded-draining ; water dominant)
(5) Terras Soil
(6) Shoal Soil

(III) *Zonal Soils**
This group is not represented in the cotton-growing areas whose soils are all too immature to show the full impress of climate.

(3) AREAL EXTENT: Table I gives the approximate acreage of each of the six chief soil-types within the four main cotton-growing islands. The values were obtained by means of a planimeter applied to provisional soil-maps.

This table shows that about two-thirds of the total area of the four cotton-growing islands is cultivable, the rest (mostly the higher lands) being in forest or scrub. The proportional amount of cultivable land varies in the different islands from 90 per cent. of the whole area in Nevis, 83 per cent. in Montserrat, 60 per cent. in St. Kitts to 52 per cent in St. Vincent. The four free-draining soil-types together comprise about 64 per cent. of the total cultivable area, Lithosol and Yellow Earth making up 58 per cent. and being represented in nearly equal amounts. The worst-drained soil, namely Shoal, comprises over 30 per cent. of the total cultivable land, more than half of it occurring in Nevis. The most widespread soil-types are Lithosol, Yellow Earth and Shoal.

Cotton lands : Not all the cultivable land is cultivated and only a small proportion of the cultivated land is planted in cotton during any one season.

Further, the average yield of cotton per acre varies widely from year to year and from one island to another. The main differences are shown in Table II.

TABLE I

Areal Extent of Chief Soil-Types

(*Thousands of acres*)

	Uncultivated (Mainly forest)	Cultivable	Cultivable Land						
			Free-draining				Impeded-draining		Per cent.
			Alluvial-Colluvial	Lithosol	Yellow Earth	Brown Earth	Terras	Shoal	
	(Acres x 10^3)		(Acres x 10^3)				(Acres x 10^3)		
St. Vincent ..	40.0	43.7	2.3	7.2	25.3	—	4.5	4.5	39.7
Montserrat ..	3.8	19.6	0.2	2.1	1.7	4.4	0.7	10.5	17.8
Nevis ..	2.4	23.0	—	4.6	—	—	—	18.4	20.9
St. Kitts ..	16.4	23.9	—	15.2	7.4	—	—	1.3	21.6
Totals ..	62.6	110.2	2.5	29.1	34.4	4.4	5.2	35.0	—
Per cent. ..	36.2	63.8	2.3	26.5	31.0	3.9	4.6	31.7	100.0

TABLE II

Areal Extent of Cotton Lands and Yields of Cotton Per Acre

	Cultivable	Cultivated	Planted in Cotton		Yields of Cotton Lint	
			1921-42 (21 years average)	1939-43 (last 4 years average)	1921-42 (21 years average)	1939-43 (last 4 years average)
	(Acres x 10^3)		(Acres x 10^3)		(Pounds per acre)	
St. Vincent	43.7	40.0	3.6	4.7	117	115
Montserrat	19.6	7.0	3.4	4.6	181	184
Nevis	23.0	7.0	2.0	3.5	108	128
St. Kitts	23.9	17.0	1.2	1.4	184	206

Note : Agricultural data taken from "Agriculture in the West Indies"; Col. No. 182, 1942, and Report on 8th and 9th meetings of W.I.S.I.C.A., Trinidad, 1944.

*The chief *Zonal* soil in the West Indian volcanic islands is *Red Earth*, comprising Red, Brown and Yellow "Lateritic" soils variably podsolised. These occur in Grenada, St. Lucia and Dominica but not in the drier cotton-growing islands.

TABLE III

Generalised Laboratory Data for Profile Samples of Cotton Soils

	Re-action	Index of Texture	No. of	Top 6 ins.			Second 6 ins.			Second foot			Whole profile (0-5 ft.)		
	pH	I.T.	Cases	O.M.	N	C/N	O.M.	N	C/N	O.M.	N	C/N	O.M.	N	C/N
(A) Free-Draining Soil-Types															
(I) Alluvial-Colluvial Soils															
St. Vincent															
East ..	6.5	10	7	2.1	.11	10.8	2.0	.10	10.8	1.4	.08	10.1	1.2	.06	10.8
West ..	6.6	9	10	2.3	.12	10.8	1.5	.09	9.9	1.1	.07	9.2	1.1	.06	10.0
Montserrat															
East ..	7.0	3	5	1.2	.07	10.8	1.1	.07	10.8	0.4	.04	6.8	0.7	.05	9.1
West ..	6.6	3	3	1.3	.08	10.2	0.9	.06	8.2	0.4	.03	8.1	0.6	.04	8.8
(II) Lithosol															
St. Vincent															
East ..	6.5	3	7	1.8	.10	11.5	1.0	.03	10.5	1.2	.07	10.9	1.1	.05	11.6
West ..	6.6	6	2	2.7	.14	10.6	2.6	.09	11.7	2.0	.05	10.7	1.3	.05	9.3
Montserrat															
East ..	6.7	3	2	1.9	.09	12.0	1.9	.08	13.1	—	—	—	—	—	—
South ..	7.2	7	4	1.9	.10	10.7	1.4	.09	8.6	0.9	.06	9.2	1.0	.07	9.3
West ..	6.6	4	13	1.7	.09	10.9	1.2	.07	11.0	1.0	.05	10.1	0.7	.04	10.0
St. Kitts															
East ..	6.2	4	3	3.1	.14	10.5	—	—	—	—	—	—	—	—	—
West ..	6.2	3	5	2.5	.13	11.2	—	—	—	—	—	—	—	—	—
(III) Yellow Earth															
St. Vincent															
East															
High level ..	6.5	19	10	2.8	.16	10.5	1.6	.11	9.4	1.5	.09	10.2	1.2	.07	9.0
Low level ..	6.7	13	10	2.8	.13	10.8	1.8	.09	9.6	1.2	.08	9.9	1.2	.07	10.0
Montserrat															
West ..	6.5	8	8	2.3	.12	10.9	1.5	.08	10.5	1.2	.06	10.8	1.2	.07	10.3
St. Kitts															
East ..	6.6	5	3	1.7	.07	13.1	—	—	—	—	—	—	—	—	—
West ..	6.5	4	3	3.4	.16	13.1	—	—	—	—	—	—	—	—	—
(IV) Brown Earth															
Montserrat															
East ..	6.4	10	12	2.5	.13	10.7	1.8	.10	10.1	1.1	.06	9.5	1.4	.08	9.8
West ..	6.7	9	6	1.9	.10	10.9	0.8	.07	7.1	0.5	.04	6.1	0.8	.06	7.5
Weighted Means ..	6.6	8	113	*2.2*	*.115*	*11.0*	*1.5*	*.08*	*10.0*	*1.1*	*.06*	*9.5*	*1.1*	*.06*	*9.8*
(B) Impeded Draining Soil-Types															
(IVa) Rendzina															
Montserrat															
West ..	7.0	26	2	3.4	.18	11.1	2.3	.12	10.7	1.0	.07	8.8	1.2	.06	9.7
(V) Terras															
St. Vincent															
West ..	6.6	16	8	2.2	.13	9.4	1.3	.09	8.3	0.6	.05	8.1	0.7	.05	7.7
Montserrat															
West ..	6.7	18	4	2.9	.17	10.0	1.6	.11	8.2	0.5	.05	5.8	1.1	.07	8.0
(VI) Shoal															
Montserrat															
West ..	6.4	16	11	3.2	.17	10.8	1.2	.10	7.7	0.7	.06	6.9	1.4	.09	8.6
Nevis ..	6.7	17	9	3.1	.15	12.1	1.5	.08	9.9	0.7	.05	7.5	1.2	.08	8.3
Weighted Means ..	6.6	18	34	*2.9*	*.155*	*10.7*	*1.5*	*.09*	*8.7*	*0.6*	*.05*	*7.3*	*1.1*	*.07*	*8.3*
Weighted Means of all	6.6	10	147	*2.4*	*.125*	*10.9*	*1.5*	*.09*	*9.8*	*1.0*	*.06*	*9.0*	*1.1*	*.06*	*9.6*
For Comparison:															
Queensland															
Series (A) ..	—	—	15	2.3	.19	7.8	—	—	—	—	—	—	—	—	—
Series (B) ..	7.4	27	14	*2.9*	*.19*	*9.1*	*1.9*	*.12*	*9.0*	*1.1*	*.08*	*8.2*	*1.0*	*.07*	*8.4*

TABLE IV

Comparison of Organic Status of British West Indies and Queensland Cotton Soils

	Mean Reaction pH	Mean Index of Texture I.T.	No. of Cases	Top 6 ins. O.M.	Top 6 ins. N	Top 6 ins. C/N	Second 6 ins. O.M.	Second 6 ins. N	Second 6 ins. C/N	Second foot O.M.	Second foot N	Second foot C/N	Whole profile (0-5 f.) O.M.	Whole profile (0-5 f.) N	Whole profile (0-5 f.) C/N
(A) Free Draining Soil-Types (I, II, III, IV)															
St. Vincent ..	6.6	10	46	2.4	.13	10.9	1.7	.08	10.0	1.3	.08	10.0	1.2	.06	10.1
Montserrat ..	6.6	7	53	1.9	.10	10.8	1.3	.08	10.0	0.9	.05	9.1	1.0	.06	9.4
St. Kitts-Nevis ..	6.4	4	14	2.7	.13	11.9	—	—	—	—	—	—	—	—	—
(B) Impeded-Draining Soil-Types (IVa, V, VI)															
St. Vincent ..	6.6	16	8	2.2	.13	9.4	1.3	.09	8.3	0.6	.05	8.1	0.7	.05	7.7
Montserrat ..	6.5	21	17	3.2	.17	10.6	1.4	.10	8.1	0.7	.06	7.0	1.3	.08	8.7
St. Kitts-Nevis ..	6.7	17	9	3.1	.15	12.1	1.5	.08	9.9	0.7	.05	7.5	—	—	—
Queensland:															
*Series (A)**															
C/N above 10	—	—	3	2.5	.12	11.9		—	—	—	—	—	—	—	—
C/N 10 to 7 ..	—	—	6	2.4	.17	8.4	—	—	—	—	—	—	—	—	—
C/N Below 7 ..	—	—	6	2.2	.24	5.1	—	—	—	—	—	—	—	—	—
Series (B)†															
C/N above 10	7.2	25	6	2.8	.15	11.0	1.9	.10	11.0	1.3	.07	10.4	1.2	.07	10.7
C/N below 10 ..	7.5	29	8	3.4	.23	7.7	1.9	.14	7.5	1.0	.09	6.5	0.9	.08	6.7

*Soil samples analysed in Australia.
†Soil samples submitted by Mr. W. G. Wells and analysed at the College.

Table II shows that only about one-third of the cultivable land in Montserrat and Nevis is actually cultivated whereas more than three-quarters are cultivated in St. Vincent and St. Kitts. The small proportion of land planted in cotton in St. Vincent and St. Kitts is accounted for by the fact that arrowroot is a more important crop in St. Vincent and sugar-cane in St. Kitts. Yields per acre are evidently higher in St. Kitts and Montserrat than in Nevis and St. Vincent.

(4) Soil Fertility: This is generally assessed in terms of nutrient contents with respect to available nitrogen, phosphate and potash, as well as degree of acidity (reaction) and calcium status. Generally also the contents of organic matter and total nitrogen are considered, and finally the presence or absence of abnormal amounts of salts as revealed by high electrical conductivity values are brought into account. During our preliminary reconnaissance soil surveys of the Islands, determinations of each of these quantities have systematically been made for the large number of soil profile and composite surface samples that have been collected. The data have been recorded in a series of "grey-books" describing our investigations*. For the purpose of the present enquiry averaged values for organic matter and nitrogen contents will be mainly considered. The relevant data are set out in Tables III and IV for different layers of the profile and for the whole profile (5 feet), so as to be comparable with the soil data for the Queensland cotton soils considered in the last article.

*(1) The agricultural soils of St. Vincent (Part VIII of Studies in West Indian Soils); F. Hardy, C. K. Robinson and G. Rodrigues: I.C.T.A., 1934, pp. 44.
(2) The agricultural soils of Montserrat (Part XI)—In the Press.
(3) The agricultural soils of St. Kitts-Nevis (Part XIII)—In preparation.

Discussion

(i) *Texture:* The index of texture values indicate that practically all these West Indian cotton soils would be classed as sands (values less than 20). The Alluvial-Colluvial soils, the Lithosols, the Yellow Earth and the Brown Earth soils would indeed be classed as light sands (values less than 10). The rest are distinctly "heavy", especially the Shoal soils, which behave in the field like real clays, much more so than their index of texture values would suggest; they are stiff and plastic when wet and hard and waxy when dry.

The content of silt and clay (particles less than 0.02 mm. diameter) of the Shoal and Terras soils is around 45 per cent. The clay fraction appears to consist mainly of beidellite which exhibits high cohesion and shrinkage. Brown Earth contains about 40 per cent. of silt and clay; Yellow Earth, about 30 per cent., and Lithosol and Alluvial-Colluvial soils about 25 per cent., though they contain more stones and coarse sand than the clayey types.

(ii) *Reaction:* None of the soils is more than slightly acid, the mean pH value being 6.6. The degree of saturation by calcium is above 60 per

cent. and generally over 80 per cent. The soils all more-or-less show the impress of a fairly high calcium content.

(iii) *Organic matter content :* By general standards for West Indian forest and cacao soils, the cotton soils would be regarded on the average as containing only medium-low amounts of organic matter. A medium amount for soils of these types would be about 3.0 per cent. for the surface 6-inch layer, whereas the mean for the 147 top-soil samples analysed is 2.4 per cent. Highest amounts of organic matter are contained in the heavier impeded-draining types. Thus, values over 3.0 per cent. are shown by the Shoal soils and many of the Terras soils and by some of the Yellow Earth transition soils.

The difference between the mean values for organic matter content of the impeded-draining soils and the free-draining soils (*i.e.* 2.9 as against 2.2 per cent.) is statistically highly significant.

Note : There is strong evidence that the organic matter content of Montserrat soils has diminished appreciably during the past 35 years. Analyses performed in 1905 by Watts and Tempany, using the same method, on soil samples that are strictly comparable with twelve of ours, show a diminution of 37 per cent. for the *top foot* layer (*i.e.*, from 2.4 to 1.5 per cent.) and a drop in C/N ratio from 10.8 to 10.0. This implies that the return of crop residues has not been commensurate with organic wastage by oxidation or erosion. Similarly, the organic matter content of Nevis soils, analysed by Watts and Tempany in 1909, seems to have diminished by about 30 per cent. (*i.e.*, from 3.3 to 2.0 per cent. for top foot layer) with a drop in C/N from 13.2 to 11.0.

(iv) *Nitrogen content :* This averages 0.125 per cent., which would be regarded as only a medium amount. The range of values is narrow ; *i.e.*, 0.07 to 0.18 per cent.

(v) *Carbon-nitrogen ratio :* This averages 10.9 for the top 6-inch layer and is seldom less than 10.0 for any of the surface soils examined. The detailed data reveal a distinct tendency for the magnitude of the C/N ratio of the upper layer of the Terras and Shoal Soils of St. Vincent and Montserrat to be lower than that of the free-draining sandy soils. This characteristic difference also applies even more distinctively to the lower layers of the Terras and Shoal soil profiles. It suggests possible differences in soil nitrate production in the contrasted soil-types as developed in various parts of the different islands, as will be explained later.

The regular drop in C/N ratio down the profile which forms a striking feature of most soils is small for sandy soils as contrasted with clay soils, probably owing to the fact that fragments of high-ratio, partially decomposed, organic residues are mechanically washed downwards from the surface, whereas for clay soils, organic penetration occurs chiefly through percolation of low-ratio products in solution, leached out of the decomposing organic matter occurring in the surface layer.

Comparison with Queensland cotton soils : The data for nitrogen content and carbon-nitrogen ratio given in Tables III and IV show a much wider range of values for the cotton soils of Queensland as compared with those of the West Indies, mainly owing to fundamental differences between soil-types. The total amount of organic matter in the soils of the two widely-separated regions is really not very different, however, averaging about 2.5 per cent. for the top 6-inch layer and about 1.0 per cent. for the whole 5-foot profile, but the total nitrogen contents show great variation, averaging 0.19 per cent. in the Queensland soils, top 6-inch layer, as against 0.125 per cent. in the West Indies soil (*i.e.*, over 50 per cent. greater in the former). This difference in nitrogen status is reflected in the values for carbon-nitrogen ratio which, on the whole, are considerably lower in the Queensland cotton soils.

It has been demonstrated in the previous article that, in the Queensland soils, highest C/N ratios are generally found among representatives of the Alluvial soil-type and lowest ratios amongst those of the Red Earth type with intermediate values for Black Earth. This does not imply that the range of C/N ratio value within any one soil-type is necessarily small ; on the contrary, both high and low ratios are found in each, depending upon whether the land has been under forest or bush, under pasture grass, or under cotton, and if the latter, for how long a period of time.

The greatest degree of similarity in general features is shown between the West Indies Shoal soil-type and the more clayey Queensland Alluvial soils having impeded drainage caused by clay-pan formation. On the other hand, the free-draining West Indies soils resemble somewhat the sandier Alluvial soils of Queensland. The Red Earth and the Black Earth soils of Queensland have no true counterparts among the soils of the four chief West Indies cotton-growing islands, except for the small amount of Rendzina representing Black Earth in Montserrat.

The nearest approach to Red Earth in the British West Indies islands growing cotton occurs in the uplands of Barbados as Terra Rossa derived from coral limestone. Soils resembling Black Earth occur in the lowlands of Barbados, in Antigua and in Carriacou, as Rendzina derived from soft limestones and marls.

Comparison with cotton soils of U.S.A. : The soils of the Great Cotton Belt of the South-Eastern States are reported to contain between 0.15 and 0.05 per cent. of total nitrogen in the top 6-inch layer and to average 0.03 per cent. in the 40-inch profile*. These values are only slightly smaller than those for West Indies cotton soils though considerably less than those for the Queensland soils. Their range of carbon-nitrogen ratio is not stated.

*"Soils and Men" ; 1938 Year Book, U.S.D.A., p. 366.

(III) Nitrate Production in West Indies Cotton Soils

The production of soil nitrate from nitrogenous organic matter is mainly a biological process involving certain specific micro-organisms. For satisfactory nitrification the soil must not be excessively acid nor lacking aeration; the presence of large amounts of highly carbonaceous organic matter inhibits the process, so that soils having carbon-nitrogen ratio greater than a certain critical value, given as 12.0 for British soils, usually show very little nitrate formation*. When the proportion of carbon to nitrogen exceeds the critical value, the surplus is eliminated as carbon-dioxide and the nitrogen remains as complex protein. The magnitude of the critical carbon-nitrogen ratio doubtless varies widely, depending on climatic and soil conditions. Under tropical conditions the critical value is probably much lower than that given for temperate soils. In the Queensland cotton soils, for example, the value appears to lie between 8.5 and 7.0.

It is important to know the approximate magnitude of the critical value for nitrification in the cotton soils of the British West Indies islands as a prerequisite to a better understanding of

*E. J. Russell, "Soil conditions and plant growth", 6th Edition, 1932, p. 313.

TABLE V

Nitrate Production by Cotton Soils

(*Comparison of data for B.W.I. and Queensland*)

	Top 6 ins.					Second 6 ins.				
	pH	C/N	Total N (%)	NO_3-N (ppm.)	$NO_3 \times 10^3$ / N Ratio	pH	C/N	Total N (%)	NO_3-N (ppm.)	$NO_3 \times 10^3$ / N Ratio
					(*I*) *Alluvial-Colluvial*					
St. Vincent :										
(1) Keartons ..	6.5	12.5	.086	22	26	6.5	13.0	.083	28	34
(2) Diamond ..	6.6	11.4	.095	33	35	7.0	9.7	.074	20	27
(3) Expt. Station ..	5.9	11.3	.132	64	49	6.2	9.4	.129	62	47
					(*II*) *Lithosol*					
St. Vincent :										
(4) Grand Sable 1 ..	6.6	14.0	.071	30	42	6.7	13.4	.042	14	33
(5) Grand Sable 2 ..	—	—	.066	23	35	—	—	.067	22	33
Montserrat :										
(1) Richmond ..	6.6	8.5	.210	44	48	6.5	7.7	.070	11	16
					(*III*) *Yellow Earth*					
St. Vincent :										
(6) Montrose ..	6.5	11.0	.125	57	45	6.6	10.1	.094	40	43
(7) Carriere ..	5.9	(7.3)	(.251)	(32)	(13)	5.8	(5.6)	(.237)	(9)	(4)
(8) Spring ..	—	10.7	.078	29	36	—	9.0	.073	20	28
(9) Belle Vue ..	—	*	.068	25	37	—	—	—	—	—
(10) Spring ..	—	*	.084	19	23	—	—	.087	21	24
(11) Union ..	—	*	.075	18	24	—	—	.065	16	25
(12) Diamond 1 ..	—	*	.074	14	20	—	—	.076	26	34
(13) Diamond 2 ..	—	*	.058	13	23	—	—	.091	18	20
Means ..	—	—	.094	30	34	—	—	.079	25	30
					(*IV*) *Terras*					
Montserrat :										
(2) Elberton ..	6.3	9.8	.150	79	52	7.9	7.8	.120	9	8
	*C/N probably mostly between 10.5 and 11.5 (Yellow Earth)									
For Comparison :										
Trinidad :										
I.C.T.A. ..	7.1	8.1	.152	35	23	7.2	8.1	.135	29	21
Queensland :										
(1) Grassland ..	7.0	—	.121	6	5	} New land				
(2) Cotton, 1 year	6.8	—	.135	36	27					
(3) do. 6 years	6.9	—	.127	38	30	} Old land				
(4) do 6 years	6.8	—	.118	48	35					
(5) do. 4 years	6.7	—	.147	56	38					

their ecological relationships and manurial requirements. Unfortunately, few nitrification studies have been carried out specifically on cotton soils in this region, but a fair amount of data is available for the soils of St. Vincent that grow both arrowroot and cotton†. The relevant information is brought together in Table V, which includes in addition certain nitrification data for soils of Montserrat (unpublished) and Trinidad* examined at the College. This table also presents data abstracted from the Queensland reports which render possible a comparison of the nitrate status of the West Indian cotton soils with that of the Queensland soils.

The data in Table V show that, for these particular examples of free-draining West Indies cotton soils, the total nitrogen content of the top 6-inch layer lies between 0.20 and 0.06 per cent. and the C/N ratio, where determined, between 14.0 and 8.1 being above 10.5 in the majority of cases, that is, well above the critical range, 8.5 to 7.0 which in Queensland apparently differentiates soils having low nitrate-producing capacity from soils having high capacity. The actual mean value for nitrate production by these soils, determined under ideal conditions in the laboratory (namely, incubation for 28 days at 30°C. with half-saturation moisture content), is 30 p.p.m. for the topsoil and 25 p.p.m. for the subsurface layer.

For Queensland soils incubated in the laboratory, nitrate values below about 30 p.p.m. usually characterise "new land" soils having high C/N ratios, whereas nitrate values above 60 are given by "old land" soils having relatively low C/N ratios. Old land soils support cotton plants that tend to "bolt", that is, to produce unfruitful rank growths susceptible to insect attack. These old land soils in Queensland have usually been out of forest or bush or pasture for five or more years so that they may have suffered surface erosion or their organic matter may have deteriorated biologically through the diminution of their supply of litter or plant residues.

The amount of nitrate produced by a soil depends on two main factors ; (*a*) the total content of nitrogen, and (*b*) the carbon-nitrogen ratio of the nitrogenous organic matter undergoing nitrification. Thus, since the average amount of nitrogen in the cotton soils of Queensland is considerably higher than that in the West Indies cotton soils, their capacity for producing nitrate should also be higher. For the purpose of gauging the effect of carbon-nitrogen ratio on nitrate production it is therefore necessary to express the nitrate content as a fraction of the total nitrogen content. Hence, when comparing soils, the proportionate amounts of nitrate given by each unit of total nitrogen present should be calculated, that is the NO_3/N ratio should be stated. This accordingly has been done in Table V. The Queensland standards now become 20 and 24 p.p.m. (instead of 30 and 60 p.p.m.) on the assumption that the mean total nitrogen content of new land soils is 0.15 per cent. and of old land soils, 0.25 per cent., based on actual analyses recorded in the previous article. If the lower limiting value, NO_3/N 20, be accepted for "old land" soils, then the data in Table V indicate quite definitely that the West Indies cotton soils resemble the "old land" kind, the mean value for the NO_3/N ratio being 34 for topsoils and 30 for subsurface layers. This is what would be expected since the majority have been under cotton cultivation for a long time. They should thus be capable of producing fair though not necessarily large amounts of nitrate under ideal conditions for nitrification.

The data in Table V and the more extensive data in Tables III and IV, indicate that the critical C/N ratio for nitrate production in West Indies cotton soils (or at least the free-draining soils of St. Vincent) is about 10.5 or perhaps lower, though the meagre experimental evidence is insufficient to warrant final statement. It appears at any rate to be somewhat higher than that for the Queensland cotton soils.

The single example of impeded-draining soil in Table V (Montserrat Terras) shows a relatively low C/N ratio and a high NO_3/N ratio, implying that its nitrate-producing capacity is greater than that of free-draining soils, a fact which agrees with prediction. The single Trinidad example (free-draining College Farm sandy soil under cultivation for a very long time) also has low C/N but its nitrifying capacity is only medium.

The relationship between nitrate production and nitrate fluctuations in cotton soils exposed to varying degrees of leaching depending on the prevailing rainfall and the effects of these on the growth of the cotton plant will be considered later after the differing climates of the main cotton-growing areas have been described.

(IV) The Climate of the West Indies Cotton-growing Areas

General : The climate of the cotton-growing areas of the West Indies islands is that of their driest parts, since only the driest parts lying within the coastal belts can successfully be utilised for cotton cultivation. The rainfall within these coastal areas is nevertheless quite high in some cases though it may differ in amount between the leeward and the windward sides. For example, in St. Vincent, the mean coastal rainfall is 84 inches a year, with 93 inches for the leeward side and 75 inches for the windward. For Montserrat, the corresponding figures are, mean, 52 inches ; leeward, 61 inches and windward, 42 inches ; St. Kitts (coastal rainfall, 54 inches) and Nevis (47 inches) do not show this dissimilarity between the leeward and windward sides. Other British West Indies cotton-growing

†The agricultural soils of St. Vincent ; Pt. VIII of Studies in West Indian Soils ; F. Hardy and C. K. Robinson and G. Rodrigues, I.C.T.A., 1934.

*Seasonal fluctuations of soil moisture and nitrate in a humid tropical climate (Trinidad, B.W.I.). F. Hardy, *Tropical Agriculture*, 1946, XXIII, pp. 40-49.

areas have much lower mean rainfalls, for example, Antigua, 40 inches and Union Island in the St. Vincent Grenadines, 30 inches.

Mean maximum temperature within the cotton-growing areas is 88°F and mean minimum, 73°F. Temperatures above 93°F or below 60°F are rarely recorded. Atmospheric humidity is lowest around 2 p.m. though seldom below 50 per cent. The air is saturated for most of the night and dew is conspicuous in the early morning. The north-east Trade Winds are persistent during the dry months. Exposure varies greatly, depending on topography and the nearness of high forest or tree belts comprising natural or artificial windbreaks. Hurricanes are likely to occur in all the islands during the late summer and autumn months.

Rainfall distribution: This is of paramount importance in cotton-growing regions in general and in those of the West Indies in particular. Here mean monthly rainfalls show widely divergent magnitudes, the divergency being greatest in St. Vincent. This is clearly shown by the data in Tables VI and VII and the diagram which indicate the unique features of the rainfall of St. Vincent as contrasted with that of other cotton-growing areas.

TABLE VI

Comparative Monthly Rainfall Data

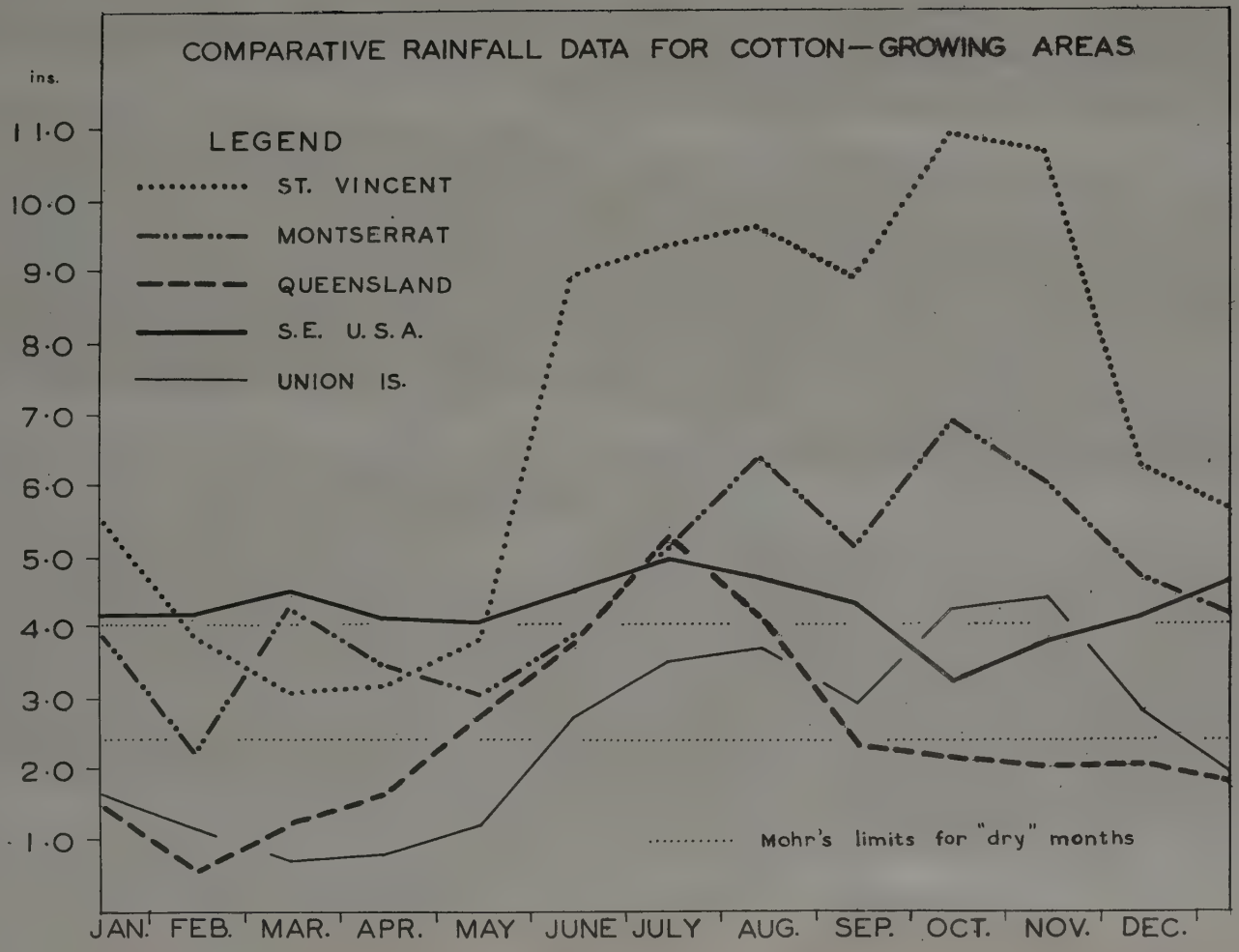
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals (ins.)
St. Vincent ..	5.48	3.89	3.03	3.18	3.79	8.90	9.33	9.49	8.81	10.93	10.61	6.12	83.56
Montserrat ..	3.97	2.19	4.28	3.31	3.07	3.86	4.97	6.27	5.07	6.79	5.88	4.57	54.23
St. Kitts ..	3.16	2.21	3.19	3.30	3.14	3.74	4.52	6.33	6.51	6.09	5.45	4.03	57.67
Nevis ..	3.12	2.22	3.12	2.25	3.22	2.82	4.21	6.31	4.18	6.24	3.51	4.01	45.21
Barbados ..	2.53	2.01	1.81	1.45	1.51	3.97	5.41	7.19	6.99	6.93	8.25	3.87	51.92
Carriacou ..	3.54	2.12	1.80	1.82	2.35	4.75	6.22	5.55	5.76	6.26	6.07	5.02	51.26
Antigua ..	2.16	2.05	2.62	2.31	2.67	2.62	4.09	5.35	5.95	5.53	4.56	3.53	43.44
Union ..	1.65	1.17	0.70	0.80	1.22	2.76	3.50	3.71	2.95	4.25	4.42	2.84	29.97
For Comparison:													
Cotton Belt U. S. A. ..	4.16	4.16	4.48	4.08	4.00	4.48	4.94	4.64	4.20	3.10	3.64	4.04	49.92
Queensland ..	1.46	0.52	1.16	1.64	2.74	3.71	5.23	4.04	2.17	2.09	1.88	1.92	28.56
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	

(1) British West Indies data after S. H. Evelyn, 1931; records for *Botanic Stations* (Kingstown; Grove; La Guerite; Charlestown; Codrington; Hillsborough; St. Johns; Union). Means for years 1920-30.
(2) U.S.A. data from "Climates of the continents", W. G. Kendrew, 1927.
(3) Queensland data after W. G. Wells; *Annual Reports* of *Expt. Sta.*, E.C.G.C.

TABLE VII

Rainfall in Relation to Growing Cycle of Cotton

	Three wet months (Sept.-Nov.)	Two drying months (Dec.-Jan.)	Four dry months (Feb.-May	Three wetting months (June-Aug.)	Totals (ins.)
St. Vincent	30.35	11.60	13.89	27.72	83.56
Montserrat	17.74	8.54	12.85	15.10	54.23
St. Kitts	18.05	7.19	11.84	14.59	51.67
Nevis	13.93	7.13	10.81	13.34	45.21
Barbados	22.17	6.40	6.78	16.57	51.92
Carriacou	18.09	8.56	8.09	16.52	51.26
Antigua	16.04	5.69	9.65	12.06	43.44
Union	11.62	4.49	3.89	9.97	29.97
For comparison:					
Cotton Belt U.S.A. ..	10.94	8.20	16.72	14.06	49.92
Queensland	6.14	3.38	6.06	12.98	28.56


COMPARATIVE RAINFALL DATA FOR COTTON—GROWING AREAS
ins.
11·0
10·0
9·0
8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·0
LEGEND
ST. VINCENT
MONTSERRAT
QUEENSLAND
S.E. U.S.A.
UNION IS.
Mohr's limits for "dry" months
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEP.
OCT.
NOV.
DEC.

The wet season usually begins near the end of May in St. Vincent and about a month later in the other three chief cotton-growing islands. It develops rapidly in St. Vincent, reaching nearly 10 inches a month during July to November but falling off in December. In the three drier islands, it develops more tardily and averages about 6 inches during August to October. There is a slight diminution in rainfall in September in each island suggesting a brief "Indian Summer". The driest months are March and April in all four islands ; less than 3.5 inches of rain falls in each of these months, the average being 3.2 inches for the four chief islands and 1.8 inches for the others.

Comparison with the U.S.A. Cotton Belt : The monthly rainfall here is remarkably uniform, averaging just over 4 inches. Seasonal division into wet and dry periods is indefinite. Monthly variations mainly concern temperature.

Comparison with Queensland : The seasons here are reversed as compared with the West Indies*. The Queensland winter is cool and very dry and the autumn is also dry but the rest of the year is relatively wet, about as wet as Nevis but less than half as wet as St. Vincent. Rainfall amount and distribution in the Queensland cotton belt are nearly the same as for Union Island (*see* Diagram).

Rainfall intensity : The rate at which rain falls on the land is an important factor in soil wetting. If the showers are intense, much water may run off and escape absorption ; If diffuse, much or all may be lost by evaporation from vegetation and soil surface. The most "effective" showers have intermediate intensity, but these cannot be fully absorbed unless the soil's surface possesses high infiltrability or receptivity. Nor can the water penetrate deeply unless the soil has suitable permeability, imparted either by a coarse-grained texture if a sand, or by a crumby structure, or a pronounced crack system, if a clay.

The classification of rain-showers adopted in Queensland† into "torrential" (falling at a greater rate than 0.75 inch per hour), "medium" (0.75 to 0.41 inch per hour) and "light" (less than 0.41 inch per hour), unfortunately cannot be applied to rainfall in the British West Indies cotton areas because recording raingauges are not in regular use there. At the College in Trinidad, where a recording raingauge was installed many years ago, analysis of the daily rainfalls has shown that, in an average year, 17 per cent. of the total rain falls in torrential showers, 21 per cent. in medium and 62 per cent. in light showers (17 years' records). The proportion of medium-shower rain, provisionally regarded as "effective" with regard to the soil moisture relations of the growing plant, has varied from 12 per cent. (1934) to 28 per cent. (1937) of the total rain. The least amount of medium rain was 6.1 inches (1934) and the greatest, 22.2 inches (1938). Doubtless similar or even greater variations occur in the amount of effective rainfall within the cotton-growing areas outside of Trinidad.

Comparison with Queensland: The seasons to the 1941-42 report for the Cotton Research Station, the percentage of torrential rain in the cotton belt of Queensland lies between 42 and 24. Light showers generally comprise about 50 per cent. of the total rain, so that medium showers average about 17 per cent. which is somewhat less than the figure for the College medium rainfall. The mean total rainfall in Queensland, however, is only 28 inches, so that the yearly quantity of rainwater that may become effective is less than 5 inches, corresponding with an abnormally dry year in Trinidad.

Evaporation : Another method of approximately assessing the amount of evaporation that takes place from the soil surface when wetted by rain has been proposed by Mohr in Java*. By directly measuring the evaporation from volcanic Yellow Earth soil contained in cylinders set up out of doors, Mohr established the following relation : $E = 2.4 + \frac{1}{8} R$,

where { R = monthly rainfall in inches,
E = evaporated water.

This expression implies that monthly rainfalls of magnitude 2.4 inches or less completely evaporate from the soil surface without penetrating, and that rainfalls in excess of 2.4 lose an additional one-eighth of their quantity also by evaporation.

Mohr's formula has been tested at the College in Trinidad where extensive data pertaining to evaporation from a free water surface exposed in an open-pan evaporimeter and in Livingston white-bulb atmometers are available. It was found that a better fit is obtained when Mohr's formula is modified to $E = 4.0 + \frac{1}{8} R$. This higher constant, 4.0, had indeed already been suggested by Mohr as marking a possible better limit for evaporated rainfall, at least for relatively dry climates. The lower value, 2.4, may still be retained, however, to mark the upper limit of truly evaporated water and the higher value, 4.0, to mark the lower limit of monthly rainfall which may soak into the ground or partly run off the surface.

Comparison between data obtained at the College from the analysis of rain showers which estimates evaporated rain as "light" showers and data obtained by Mohr's method of calculating evaporation loss from monthly rainfall figures,

*The longitude of Eastern Australia is 150° E., and of the Lesser Antilles, 60° W. ; difference, 210°. The Azores (30° W.) are exactly "under" Queensland and Western Australia (120° E.) is exactly "under" the Lesser Antilles.

† Seasonal fluctuations of soil moisture and nitrate in a humid tropical climate (Trinidad, B.W.I.). F. Hardy, *Tropical Agriculture*, 1946, XXIII, pp. 40-49.

* The evaluation of soil moisture, F. Hardy, *Tropical Agriculture*, 1946, XXIII, pp. 66-75.

has shown a fair agreement except, of course, for dry season months having rainfall less than 4 inches.

According to Mohr's formula, months whose rainfall is 4.0 inches or over may be regarded as "wet" months and months whose rainfall is 2.4 inches or less as definitely "dry" months from the point of view of their effectiveness in wetting the soil. Months having rainfall between these limits may be designated "intermediate"; their degree of wetness or dryness depends mainly on whether they follow wet or dry months. Thus, the rainfall of each month of the year for any particular station may be identified as "wet" or "intermediate" and the climate at that site accordingly classified on some such arbitrary scheme as Mohr's, as follows :

Class	Climate	Number of Dry Months	Wet Months	Intermediate
Group I	(*a*) Continuously wet	0	12	0
	(*b*) Continuously moist	0	11-6	1-6
Group II	Weak dry season	1-2	11-9	0-2
Group III	Marked dry season	2-3	8-6	1-4
Group IV	Intense dry season	4-5	7-5	0-3
Group V	"Fierce" dry season	6-8	5-4	0-2

According to Mohr's scheme, the College station would be classified between Group III (marked dry season) and Group IV (intense dry season) although its classification would vary from year to year because of the inconstancy of its annual rainfall. Thus, in 1934 (the driest year on record), the College station would be placed in Group V (fierce dry season) with 6 dry months and 5 wet, whereas in 1927 (the wettest on record) it would be put into Group II (weak dry season) with only one dry month and 11 wet.

With regards the West Indies cotton-growing islands, the monthly rainfall data in Table VI indicate that, of the four experiment stations included therein, the St. Vincent station would be placed in Group I (*b*) (continuously moist), the Montserrat and the St. Kitts stations in Group II (weak dry season), bordering on Group III (marked dry season) the Nevis station in Group III (marked dry season) bordering on Group IV (intense dry season), the U.S.A. south-eastern stations in Group I (*b*) (continuously moist) although the rainfall of 10 wet months in the Great Cotton Belt is only just over 4.0 inches, and the Queensland station in Group V (fierce dry season). Other West Indies stations would be classed on monthly rainfall as follows :— Carriacou, Barbados and Antigua, Group IV (intense dry season) and Union Island, Group V (fierce dry season). Doubtless the groupings for the various islands would differ from year to year, as at the College, and they would differ also between different stations in each island as compared with the central experiment stations named in Table VI. It should be possible, however, to establish the range of grouping, both in time and in place, by reference to the detailed rainfall records kept by the island agricultural departments, but this has not yet been attempted except in the case of Montserrat for which the available data indicate that, for an average year, the leeward side of the island would be classed as Group I (*b*) (continuously moist), the north as Group II (weak dry season) and the windward and south as Group III (marked dry season).

The importance of classifying the monthly rainfall data for every station within each cotton-growing area lies in the aid it affords in the selection of suitable planting seasons and in the choice of manures and manuring times for the cotton crop. It has particular value in determining the nitrate relations of cotton soils because, during monthly periods when all the incident rainfall evaporates without penetrating, nitrate probably accumulates within the rooting zone, whereas during periods when a large proportion of the rainfall soaks into the ground and percolates downwards, nitrate may be removed in solution and lost in the drainage. These different aspects of the subject will be considered in the next part of this article.

Summary

1. This article describes the soil-types in the four chief British West Indies cotton-growing islands ; viz., St. Vincent, Montserrat, St. Kitts and Nevis.

2. The soil-types comprise two Azonal soils (Alluvial-Colluvial and Lithosol), three Calcimorphic Intrazonal soils (Yellow Earth, Brown Earth and Rendzina) and two Hydromorphic Intrazonal soils (Terras and Shoal).

3. Each of these is immature and has been derived from fragmental volcanic rocks of andesitic relationship.

4. The approximate acreages occupied by each soil type and of the land devoted to cotton-growing in the four islands are stated and compared.

5. Averaged results of a large number of chemical analyses for organic matter and nitrogen contents of the soil-types are tabulated for each island and compared with those for the cotton soils of Queensland that were described in Part I of this article, and with those of the South-Eastern United States of America.

6. The laboratory data reveal the fact that British West Indies cotton soils consist of slightly acid sands containing only medium amounts of organic matter and nitrogen in the top 6-in. layer, diminishing rapidly down the profile. The impeded-draining soil-types contain significantly more organic matter and nitrogen than the free-draining types. The actual amounts are largest in Montserrat and Nevis Shoal soil and smallest in Montserrat Alluvial-Colluvial soil.

7. The organic matter contents of the Queensland cotton soils are of the same order of magnitude as those of the British West Indies soils, but their mean nitrogen content is much higher. Carbon-nitrogen ratio is therefore lower in the Queensland soils, being generally less than 9.0 (top 6-in. layer), whereas for the West Indies soils it generally is around 11.0, tending to be lowest in the impeded-drainage soils. (Table III.)

8. The nitrogen content of the cotton soils of the south-eastern States is slightly lower than that of the soils of British West Indies.

9. The importance of total nitrogen content and carbon-nitrogen ratio in soil nitrate formation is discussed. It is pointed out that, not only high total nitrogen content, but also low carbon-nitrogen ratio favour nitrate production. Relevant data for nitrate formation under incubation of representative samples of British West Indies (mainly St. Vincent) cotton soils are tabulated. It was found that, for the free-draining West Indies soils, amounts of nitrate above the median value (30 p.p.m.) which separate high nitrate-producing "old land" soils on which cotton plants "bolts" from low nitrate-producing soils supporting normal cotton crops in Queensland, are produced by soils having carbon-nitrogen ratio around 10.5 which is much higher than the apparent critical ratio (C/N 8.5) for Queensland cotton soils. Evidently the critical value for carbon-nitrogen ratio is higher where the climate is wetter and, for the West Indies, it approaches nearer the characteristic value for temperate regions, namely, 12.0. (Table V.)

10. For the ultimate purpose of correlating nitrate-producing capacity and the physiological behaviour of the cotton plant with the nutrient status and the manurial needs of cotton soils, the variable climates of the chief British West Indies cotton-growing islands are described, with particular reference to total amount of rainfall, its monthly distribution, and the intensity of rain showers. It is suggested that only "medium" showers (falling at an arbitrary rate between 0.75 and 0.41 ins. an hour) are "effective" in growth, showers of higher category producing run-off water and showers of lower category being mainly evaporated.

11. Mohr's formula connecting evaporation (E) with monthly rainfall (R) (*i.e.*, $E=2.4+\frac{1}{8}R$) is employed to identify "dry" months, and its modification ($E=4.0+\frac{1}{8}R$) to identify "wet" months, so that the degree of soil humidity, and consequently the chances of nitrate accumulation and of nitrate removal by leaching, may be gauged for each area merely by scrutiny of monthly rainfall records.

THE SOUR ORANGE STOCK SITUATION IN SOUTH AMERICA

A summary of the sour orange situation in South America was recently prepared by A. F. Camp (*Calif. Citrogr.*, 31, 77) after a trip to several South American countries. The trouble is called "podredumbre de las racaillas" in Spanish-speaking countries, and "tristeza" in Brazil. The cause is unknown. Affected trees decline without any specific symptoms and closely resemble trees declining from waterlogging of the soil. Trees turn yellow and lose part of their leaves; growth is very scant and the trees die back from the periphery with symptoms of zinc deficiency and general starvation. Feeder roots die and are not replaced; later large roots die. Trees go out of production or die in periods varying from a few weeks to from 2 to 3 years after symptoms appear. Orange, grapefruit and mandarin on sour orange stock are all definitely affected, but mandarins and grapefruit usually outlive sweet oranges. Lemons on sour orange stock appear to be immune, and sweet oranges, grapefruit and mandarins on sour orange but topworked to lemons will produce sound lemon tops. Sour orange seedlings are immune. Sweet orange stock apparently is entirely immune; other stocks such as rough lemon, Rangpur lime, sweet lime, grapefruit and *Poncirus trifoliata* are believed to be occasionally affected, but this is not confirmed. It occurs on a wide variety of soils. No control is known and in all areas affected it has been necessary to replant with other stocks. The method of transmission is unknown. In no case has transmission by any method been proved experimentally. The areas affected are South Africa, Java and South America (Argentina, Brazil, Paraguay and Uruguay). (*Hort. Abst.* 16, 122.)

THE LOW TEMPERATURE RESEARCH STATION, 1941-1945

BY

E. R. LEONARD

(Officer in Charge)

Introduction

The passage of a further five years since the last interim account of the work of the Low Temperature Research Station (1) finds it at a fresh crisis. The decision of the Colonial Office has been received that the Station shall be placed on a care and maintenance basis as on October 1st, 1946, with a view to its being available, at a later date, if required for investigations of food technology problems. A two-year *ad hoc* project on refrigerated "gas-storage" of bananas is to be set up in Jamaica, using some of the apparatus at the Trinidad Station and two of the cold storage chambers at the Low Temperature and Marketing Experiment Station, Kingston, Jamaica, under the control of the Commerce and Industries Department. The project will be under the supervision of the Commissioner of Commerce and Industries and under the scientific direction of the Department of Scientific and Industrial Research in Great Britain.

Empirical storage trials of different banana varieties and hybrids are at present in progress in Jamaica.

The Station's Finances and Staff

The programme of work as laid down by the Low Temperature Research Sub-Committee of the Colonial Advisory Council of Agriculture and Animal Health in 1936 has been continued, subject to restrictions imposed by wartime shortages of staff, apparatus and supply of fruit. Frequent changes in the locally recruited assistant staff and in the engine-room operators occurred with disruption of the programme. (In this respect the Station fared considerably worse than most College departments, as a result, largely, of its non-permanent basis).

Dr. Barnell left the Station in 1943 to take up an appointment with the Ministry of Food, Dehydration Division, in the United Kingdom.

Funds were provided on the basis of a two-year-, followed by three one-year-, grants under the Colonial Development and Welfare Act, 1940. The Colonial Advisory Council was notified on each occasion of renewal of grant of the difficulties being encountered and the consequent protraction of the programme on refrigerated "gas-storage".

The conditions of the grants (expenditure confined to the sterling area, etc.) under wartime restriction of supplies, accentuated the difficulties of the staff in carrying out the programme. Similar conditions do not appear to have been laid down for College departments.

The period has thus again been one of considerable anxiety for research officers. The investigation of food storage problems, however widely the mandate for its prosecution is interpreted, calls for considerable specialization of activities. When the work also involves the partial isolation from fellow workers on similar problems as a result of its being conducted in the tropics, there exists a very strong argument in favour of the research station being conceived on a permanent and adequate basis, with interchange of staff with institutions in temperate climates.

Operation of the Station's Equipment

A brief account of the operation of the Station's equipment since its reconditioning in 1937 and some of its shortcomings were discussed in the previous report (1).

The room coolers were supplied by the refrigerating manufacturers with the specification that room air temperature could be maintained with a 10 ° F. brine/air temperature difference. This has been found to obtain in practice but involves low humidity, since considerable deposition of water occurs on the cooler coils. (The dew point at 53 ° F. and 90 per cent. R.H. is 50 ° F.). No advantage was found from the additional 50% increase in cooler surface supplied to one room in 1937 (2). It is possible, however, that a lower brine/air temperature difference could have been used. This is impossible with the present common brine supply to four rooms. The system, in effect, constitutes an air-conditioning unit. The ripening rooms, whose cooler-surface/room-air-volume ratio was approximately doubled by the division effected in 1937, also have too low humidity, a 10°F. brine/air difference being the minimum to give stable temperatures.

A brine/air temperature difference of 5o°F. is used at the U.S.D.A. cold storage laboratory at Beltsville, Md. (3) and at the new government cold stores in Great Britain (4), whilst a maximal difference of 4°F. is used in the cold rooms at the Central Experiment Farm, Ottawa (5).

The pine-cone fibre hygrostat, supplied with the humidifier spray for use in one ripening room in 1937 (2), apparently lost its response to humidity changes after a few years.

The gradual accumulation of dust on the heater mats in the air trunks has been found to diminish the air delivery to the room concerned and to increase the air leakage from the trunk, so that a lower brine temperature in the cooler has been required to maintain the room air temperature, with consequent lower humidity. Frequent removal of the heater mats and cleaning has been necessary. This is an additional reason for elimination of the heater mats.

An improvement in the refrigerating equipment of one of the cold storage chambers was effected in 1945 by the installation of a modulating valve in the return brine pipe from the cooler, with thermostat phial at the end of the delivery trunk. This replaces the original manual control of brine from the main brine tank, with heater mats in the delivery air trunk controlled by mercury-in-glass thermostat through a magnetic relay, as described in an earlier publication (2). The same accuracy (about ± 1°F.) control of temperature is obtained, though with a temperature cycle corresponding to the brine temperature cycle (40° to 45°F.) caused by intermittent operation of the ammonia compressor. An increase in the room humidity, from mean value of 80% to 88% R.H., has resulted. Further improvement would call for stabilisation of the brine temperature by the use of a separate brine tank for each room, with automatic injector valve and brine circulating pump to cooler, such as is already in use for the two ripening rooms (2). This equipment was advocated in 1936 but proved beyond the scope of the grant allowed for reconditioning the Station (1).

Experiments on Gas-Storage

At a meeting of the Low Temperature Sub-Committee in July, 1940, it was decided that the preliminary experiments (6) had shown that refrigerated gas storage of bananas might be of considerable practical importance. It was recommended (i) that it should be tried out under commercial conditions, (ii) that a trial, on a fair scale, should be carried out in a chamber at the Low Temperature Research Station and (iii) that tests should be made using various coatings for bananas.

(i) Owing to the deterioration of the shipping situation and the consequent embargo on importation of bananas to the United Kingdom the first project was abandoned. (ii) Dr. Barnell carried out a trial in a small refrigerated chamber (500 cu. ft.) at the Station, without any modification to the equipment, and using 116 bunches (approximately 6,100 lbs.). Cooling to the storage temperature of 53°F. was carried out as rapidly as possible after loading. No appreciable accumulation of carbon dioxide gas was observed during the cooling down nor during the subsequent 18 days' storage. No evidence of retardation of ripening or suppression of "chilling" was evident as compared with fruit in an adjacent room receiving a "blow-out" with outside air twice daily. On the basis of no leakage and known rates of respiration at 53°F., it was calculated that accumulation of CO_2 would have been at the rate of about 3% per day.

It was concluded that leakage from the room and external trunk was very considerable. The construction of the room and refrigeration equipment have been described elsewhere, ((2) p. 7, Room No. 6). Attempts were made to reduce the leakage of gas from the room. Two coats of a special paint ('Sealapore') were applied to the cement floor and the plastered walls and ceiling of the room. The door was lined with galvanized sheet iron and the space between its two rubber gaskets filled with a mixture of vaseline and beeswax so that, on closing the door, it formed a seal with the door frame. This treatment was found to have reduced leakage from the room, when the trunk was blocked off, to about that found permissible in commercial refrigerated gas storage of apples i.e. about 6% of the amount of carbon dioxide present per diem (7).

The external trunk was lined with sheet copper with joints lapped and soldered and a gland fitted at the point where the horizontal fan shaft passes through its housing to the motor. This gland was of the type described by Hardy ((8) p. 216, Fig. 79b). When the trunk thus modified was tested with its ends blocked off, the rate of leakage of carbon dioxide was found excessively high. The surrounding insulation was removed by stages and the copper lining tested under pressure with lather to indicate leaks by bubbles. When the insulation was replaced and the trunk again tested with the fan not running, only slight losses in concentration occurred. With the fan running, however, a high rate of leakage was found either with the trunk blocked off from the room or with normal air circulation between trunk and room. It appears that the static pressures set up in the trunk due to the fan very considerably increase leakage through small apertures.

The number of bends and joints necessitated by the equipment installed in the trunk (fan, cooler and heater-mats (2)), and the baffling effect of the heater-mats themselves, contribute to the difficulty of rendering the trunk gas-tight.

It is reported that similar difficulties have been experienced in New Zealand in experimental gas-stores with external trunks (Tiller, personal communication). The alternative of eliminating the external trunk by placing all the refrigerating equipment inside the room (i.e. "bunker" refrigeration or "self-contained-battery") was applicable with the type of cooler, etc., available at the Low Temperature Research Station.

Since the storage period for bananas is relatively short (14 to 16 days) compared with that for apples (six months and more) it is evident that a high degree of gas-tightness will be necessary, so that rapid accumulation of CO_2 may occur and the advantages of controlled atmospheres may be realised. A maximum of about 2.5% CO_2 was recorded on one occasion in an old type banana-carrying vessel following a period of five days during which no "blow-out" was given (9).

The use of steel cabinets has been found convenient in small scale experiments on the "gas-storage" of apples. For bananas these do not appear to afford a suitable substitute for a "gas-tight" room. The initial removal of field heat from bananas necessitates the movement of a considerable volume of air through the fruit and

must be accomplished in a short time or the benefits of low storage temperature are lost. A period of twelve hours or less is required on modern banana-carrying boats (10). Another difficulty is that, however rigorous the pre-storage grading, (by accepted local standards of size and rotundity of fingers) the storage potentialities show a considerable range, each bunch exhibiting marked individuality in the period of storage at 53°F. without chilling, and in subsequent ripening at higher temperatures. Whereas 50 or 100 apples, which may conveniently be stored in a small cabinet, may be taken as representative of the population of a shipment, a dozen bunches of bananas is only 12 "individuals". In practice in Trinidad and Jamaica (Larter, personal communication) twently or thirty bunches have been found the minimum adequate sample.

The expedient of using detached fingers, clusters, or hands from a number of bunches to obtain data on bananas from a larger number of complete bunches than could be accommodated in a small cabinet, is open to the criticism that the behaviour of such detached fruits is known to differ from that of an intact bunch, and, further, would represent a departure from existing trade practice for banana transport from the Caribbean area. (Transport of crated "singles", "clusters" and "hands" is practised in the trade from Fiji and Samoa to Australia and New Zealand and in the internal Australian trade). The cost of the fruit used in any experiment is never an item of considerable importance.

The questions to be answered are:—(a) Can "chilling" (known to exist under present conditions of banana transport) be avoided by the use of "gas-storage"? (b) Can heavier grades be used on existing routes, e.g., "heavy ¾-full" to United Kingdom in place of "¾-full", without involving "chilling"? (c) What is the maximum period for which any grade can be carried without loss of quality due to "chilling" resulting from ripening in cold storage, compared with the present limits?

(iii) Dr. Barnell carried out tests on the use of various coatings for the preservation of bananas on the lines of those found successful for apples at the Low Temperature Research Station, Cambridge (11), and in Australia (12), and patented by the D.S.I.R. He found that a solution of white rum, 10 gallons; castor oil, 3 pints; and shellac, 1.88 lb., was suitable for the dipping of banana bunches of commercial export grade for storage at 53°F. Provided the storage period was not more than a few days beyond the period of tolerance of untreated fruit, the treated fruit would remain green at 53°F. and subsequently ripen more slowly to give fruit of better appearance, with delayed onset of anthracnose, free from "chilling" symptoms and of good eating quality. Too strong a treatment gave fruit which coloured very slowly and irregularly and was of poor final flavour; too weak a treatment was of no benefit in the avoidance of "chilling". The cost was approximately 8 cts. per bunch in the experiments but on a commercial scale this could easily be reduced to half. Addition of benzoic acid and acetic acid to the dip markedly increased blemishes previously present on the skin due to bruising and scarring. Subsequent trials were made using coconut oil and olive oil emulsions. These were less satisfactory. Treatment with amyl acetate rapidly blackened bananas which did not ripen and 1% maleic acid in amyl alcohol in water provided bananas of poor appearance and only slightly delayed ripening, (c.f. 13).

Programme and Publications

Since the inception of the concentrated attack on the broblems of the metabolism of the banana in 1937 the work of the Station has been largely concentrated on obtaining and correlating data, from estimations of the respiration, transpiration and carbohydrate metabolism of Gros Michel bananas during development and ripening. The latter process has been followed, first at tropical temperatures to establish "normal" trends, then at the storage and ripening temperatures in current commercial practice for the grade of fruit, and finally during prolonged cold storage to obtain data on the metabolic changes accompanying the disorder, known previously by external and internal symptoms, as "chilling." It has thus been corrective of the results established in temperate countries using results established in temperate countries using bananas after overseas storage and, therefore, initially in different physiological condition.

Three additional contributions on chemical aspects of banana storage and ripening have been made to the *Annals of Botany* since 1941. One on respiration in different concentrations of oxygen has been submitted for publication. The former give new information on the establishment of a criterion of "eating quality" in bananas.

Liaison and Advisory Work

With wartime restrictions on travel and shipboard visits, fewer opportunities have been available for interchange of information on storage problems with engineers and other interested parties. The work at the Station has also tended to be less concerned with existing commercial practice and more with possible future developments. Nevertheless, visits have been paid by members of the U.S. Department of Agriculture, (Office of Foreign Agricultural Relations), by Paraguayan cold storage technicians, by the Director of a Brazilian Low Temperature Research Station, and by a member of the staff of the Paraguayan Servicio Tecnico Interamericano de Cooperacion Agricola. These visitors were introduced by the Food Production Mission, Institute of Inter American Affairs in Caracas, Venezuela, (since discontinued).

The advice of the Low Temperature Research Station has been sought during the period 1941-1946 on various local storage problems in the marketing of fish, cabbages, etc., by officers of the Department of Agriculture and Food Control Board. No specific wartime problems were allotted.

The Station's Future

At a meeting of the Low Temperature Sub-Committee in March, 1943, it was agreed that "it was desirable on general grounds that the Trinidad Station should be kept in being and that the technical staff should be retained. It seemed obvious that research work on the preservation of foods and vegetables must continue to be a matter of prime importance to the West Indies and it would be unfortunate if on the conclusion of hostilities, it was necessary, to start afresh with the building up of a new team".

The present decision to restrict investigations to an *ad hoc* programme of gas storage of bananas is regrettable. Much of the success of the work of the Low Temperature Research Station of the Food Investigation Board in Great Britain, has been due to the wide terms of reference laid down for its guidance. A statement of its early experience was given by its first Director (14). The aim of the Food Investigation Board becoming expert adviser or consultant to industry, so that its Station would be a work's laboratory, was rejected in favour of investigating the more fundamental scientific problems of the food industries. The problems of storage have been pursued in a quasi practical spirit, that is, the experiments have kept as close to the industrial method as may be without degenerating into empiricism.

The storage of perishable tropical produce must be undertaken at centres of production. (Very different metabolic behaviour has been found with bananas freshly harvested from those after an overseas voyage.) There is a strong case to be made for the establishment of a tropical counterpart of the Low Temperature Research Station, Cambridge, adequately equipped and staffed to undertake investigations on the many problems of food processing, storage and transport encountered between the production and consumption of tropical foodstuffs. Such a Station has been proposed in a memorandum on the centralization of agricultural research at the Imperial College (15) based on the recommendations of the Royal Commission to the West Indies (16). This recommended the extension of the use of cold storage and the continuance of investigations on storage problems at the I.C.T.A. The Royal Society Empire Scientific Conference (June-July, 1946) has recommended the use of improved methods of storing, processing and distributing foodstuffs, such as better methods of milling wheat and maize, the parboiling of rice, the drying of fish, fruit and vegetables. It urged the need for more food technologists in this connection (17).

It may be pointed out that with replacement of manual labour by mechanisation there has been a world-wide decrease in the consumption of carbohydrates in the form of cereals. These are readily stored without special precautions. Concomitant increase in the consumption of the proteinaceous, fatty and vitamin-rich foodstuffs is occurring. These, in general, require storage conditions other than those provided by nature, e.g., canning, cold storage. Further, these are the foods which are considered to be markedly deficient in tropical diets and at the same time the most subject to deterioration. Again, the concentration of population in cities, previously confined to temperate, industrial countries but now becoming general in the tropics, has produced problems of food storage and distribution never experienced by scattered rural communities. In short, there are many applications of the different food preservation processes now practised in temperate countries which have not been applied in the tropics. In particular, the advantages of low temperature storage have been utilized to a negligible extent. This is partly a reflection of lack of facilities and partly due to lack of knowledge, which can only be gained by investigations conducted in the country of production of the different crops. Citrus fruits and bananas are the only perishable tropical produce exported to any considerable extent. Again, the local market would benefit by the avoidance of gluts with depressed prices, were facilities available and utilized for short term storage of local produce. On both economic and nutritional grounds the necessary investigations should be undertaken.

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CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Comparison of Four Methods of Soil Moisture Measurements

Determinations of soil moisture under field conditions were made with tensionmeters, resistance blocks and gravimetric plugs and compared with direct determination on oven-dried samples to furnish basic data on soil-moisture variability. The performances of the instruments were judged by determinations on soil samples taken at random within a restricted area around each installation. Considerable differences between types of instrument were observed in respect of accuracy of measurement, moisture range of sensitivity, and efficiency in differentiating soil-moisture levels. On a silt loam soil plugs and blocks were better than tensiometers except at high moisture contents where tensiometers gave their best performance. On a sandy soil blocks were better than plugs, though either was satisfactory throughout the available moisture range. While no one instrument is "best" for all purposes and conditions, gravimetric plugs are most suitable for accurate measurement under the majority of soil conditions, and resistance blocks are best adapted to semiquantitative measurements of the variable field moisture of large areas. Tensiometers have a more limited range of usefulness.

(*Soils & Fertilizers*, 9, 85, 1946).

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Shrinkage and Cracking of Cementive Materials

Mr. H. H. Macey (British Refractories Research Association), in his paper on the "Cracking of Plastic Clay Articles during Drying", discussed many of the technical problems involved in manufacture. In the manufacture of any article from clay the ground raw material is mixed with sufficient water to render it capable of being moulded to the required shape, and, afterwards, it is dried to remove this water, and then fired. Problems of drying to avoid losses owing to shrinkage cracking are thus of much importance to the clay industry. A mixture of clay and water shows two distinct portions in the volume shrinkage/moisture content curve. During the first stage, the change in volume is equal to the volume of water lost, but below a certain moisture content shrinkage for all practical purposes ceases. The order of movement with which Mr. Macey was concerned here is, of course, large compared with the dimensional changes undergone by rigid solids with change in moisture content that were discussed in the previous papers. In effect, the second stage referred to by Mr. Macey, in which volume change is very small, is the parallel to the behaviour of a rigid solid. The moisture content at which the first-stage shrinkage ceases varies considerably with the type of clay, and although it generally lies within the range of 8-13 per cent. of water, it may be as high as 20 per cent. Under constant conditions of temperature and humidity, the rate of evaporation while shrinkage is taking place is constant, and very close to that of the free water surface, and it is only when the shrinkage ceases that the water surface retreats below that of the clay and evaporation is governed by diffusion through the pores and the reduced vapour pressure. Mellor explained the shrinkage behaviour of a clay by the supposition of continuous water films between the surface of the clay particles. During drying, the shrinkage of these films results in a change of volume equal to the volume of water lost, and this holds until the particles come into contact and shrinkage ceases. The thickness of the water films in a plastic clay appear from recent work to be of the order of, but probably less than, 1,000 A. (*Nature*, 158, 13, 1946).

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Comparison of Soil Nitrate Nitrogen Values under Bare Fallow and after Ploughing in Various Perennial Tropical Legumes and Cow-peas

Four perennial tropical legumes—*Calopogonium mucunoides* (calopo), *Centrosema pubescens* (centro), *Pueraria phaseoloides* (puero) and *Stylosanthes guianensis* (stylo)—after 18 months' growth were ploughed under in July at South Johnstone, on the wet tropical coast of Queensland, and soil nitrate nitrogen values were determined in four layers to a depth of 24 inches over the ensuing seven months. The mean nitrate values for the puero plots at each depth were significantly higher at the 1% level than the corresponding values for the other plots. In the top six inches of the puero plots, the mean value was 171.8 p.p.m., and the maximum was 395.6 p.p.m., in early October. The effects of yield, chemical composition of the plant material, soil moisture and temperature on nitrate nitrogen production are discussed. A high positive correlation between precipitation and leaching of nitrate is shown. Comparison with a ploughed-in area of giant cowpeas showed that only puero was superior to cowpeas in soil nitrate production. Under bare fallow, nitrate nitrogen production was not detected until mid-August and was slow until mid-September. The maximum content of 108.0 p.p.m. in the top six inches was reached in mid-January, and the mean value in that layer over seven months was 34.4 p.p.m. The importance of perennial legumes as soil improving plants in the tropics is stressed and the particular value of puero and centro is indicated. The implications of nitrate nitrogen production under bare fallow in relation to pasture and crop growth are discussed.

(*Qd. J. agric. Sci.*, 2: 170-89, *Hort. Abstr*, 16, 127, 1946).

The Editor is prepared to consider signed articles for publication in *Tropical Agriculture*. Such articles should normally vary between 1,000 to 6,000 words and may be illustrated if desired.